American Nuclear Society

2002 WINTER MEETING

"Building the World Nuclear Community –
Strategies for the Deployment of New Nuclear Technologies"
(November 17 - 21, 2002, OMNI Shoreham Hotel, Washington, D.C.)

Application 3D Dynamic Model for Estimation the Consequences of "Dirty Bomb" Blasting in Urban Conditions

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Radiation sources widely used in different industries, science and health care are most dangerous from the viewpoint of their spread, easy access and potential use to develop a radiological weapon, such as RDD or "dirty bombs".

«Terrorists could also attack a city with a “dirty bomb” in which radioactive material is dispersed by conventional explosives. The Nuclear Regulatory Commission has estimated that such an attack could cause more than 2000 immediate and long term deaths and billions of dollars in property damage if a cask of spent fuel rods were dispersed in Manhattan at midday.»

Ira Helfand, Lachlan Forrow, Jaya Tiwari
«Nuclear terrorism», BMJ, Vol. 324, 9 February 2002

Such a bomb can be developed for contamination of industrial centers, transport loading/unloading terminals and residential areas, which can affect a large sector of economy of the country. Use of a "dirty" bomb can lead to death and exposure of the population, but, as a whole, the use of the bomb is aimed at creating panics among population and social shocks of the society.

Decision making in situations of emergency related to releases of radioactive materials into the atmosphere (as a result of nuclear accident or RDD explosion) require the development of mathematical methods for prediction of radiation situation at an early stage of the accident.

The main part of the mathematical models and equations used for environmental transport and estimation of dose and risk is the module for calculation the plume dispersion.

Atmospheric Diffusion models

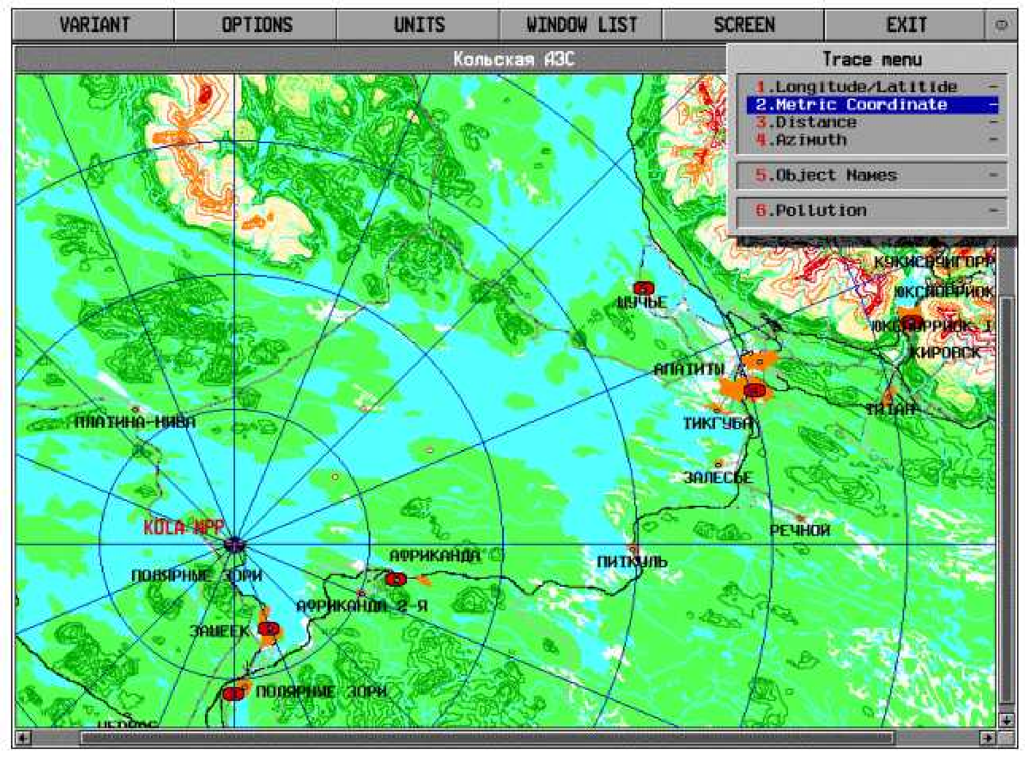
To date, a large number of transfer models of various types have been developed that differ in the scope of processes taken into consideration and the way of accounting for their impact. Among them, we should mention the so-called K-models, statistical models, models of similarity, Gaussian models. Detailed description and discussion of these models and associated theories of atmospheric transfer can be found in the numerous publications.

Atmospheric Diffusion models

In practice, most popular are the so-called Gaussian models that generalize empirically the accurate solutions to equations of advection/diffusion in a constant wind field.

They are laid into foundation of many normative techniques that are used for description of industrial release dispersion nearly throughout the world.

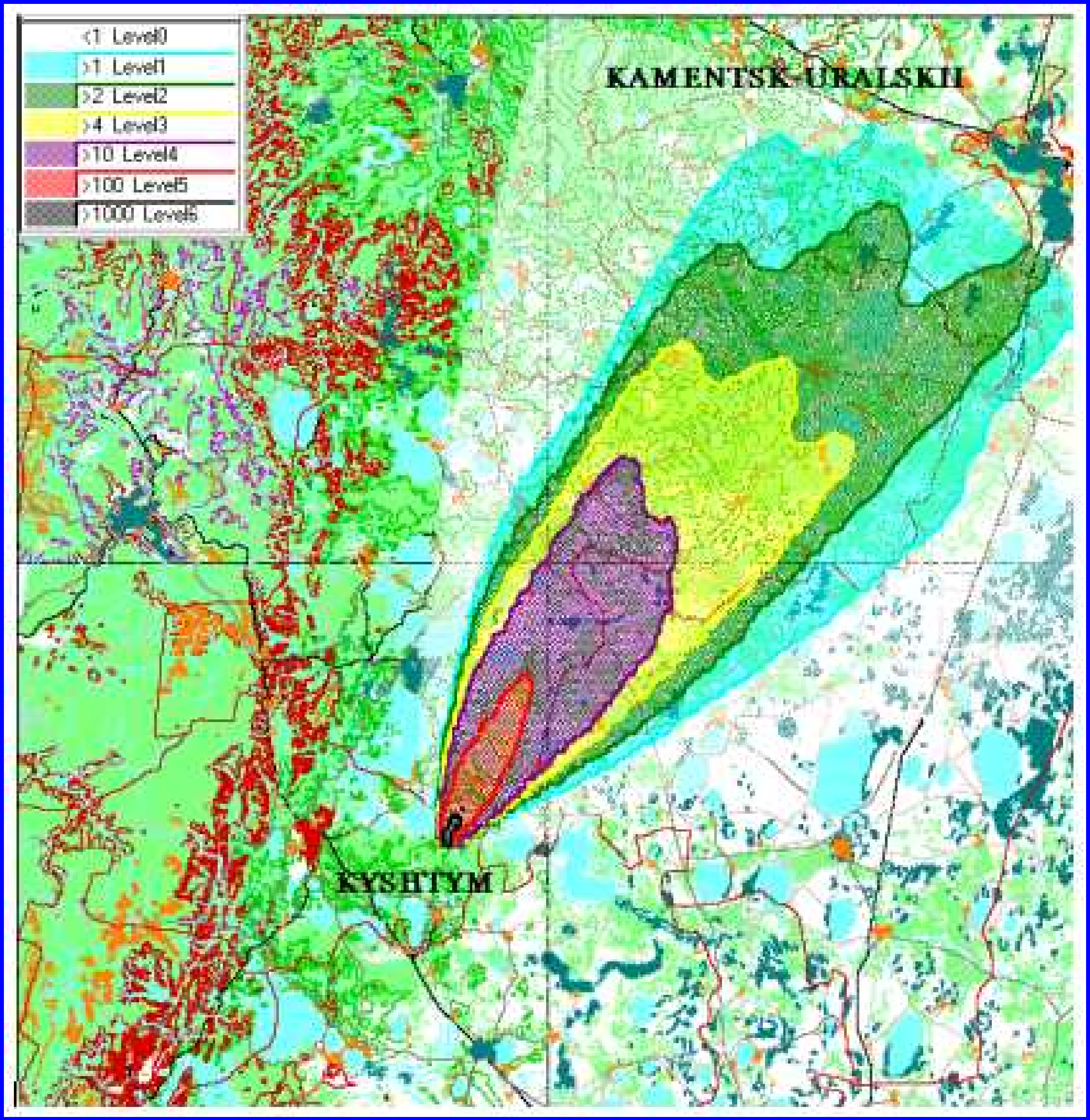
The “TRACE” code (IBRAE RAN)



A computer code using for predictions regarding the processes of dispersion of accidental releases in the atmosphere, formation of radioactive contamination of the territory, assessment of internal and external exposure doses to population.

Source model used for calculating the Kyshtym accident consequences. (Modified "TRACE" code)

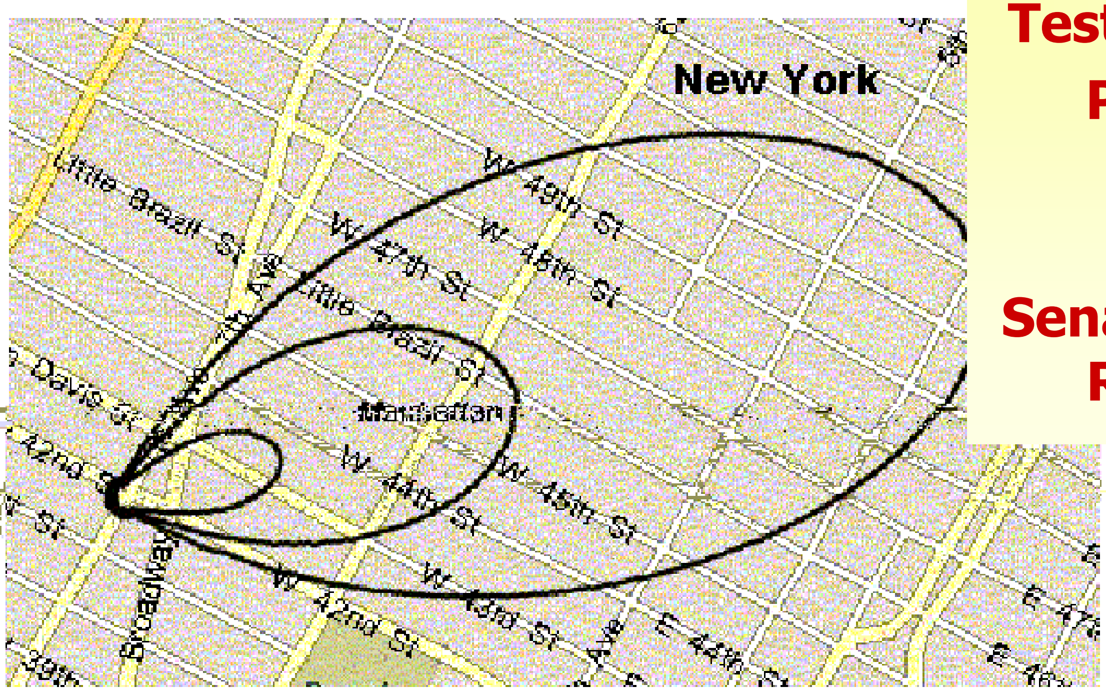
Primary data	Radioactive cloud layer number								
	1	2	3	4	5	6	7	8	9
Layer thickness, m from to	 0 20	 20 50	 50 100	 100 200	 200 400	 400 700	 700 1,000	 1,000 1,500	 1,500 2,000
Effective layer altitude, m	10	35	75	150	300	550	850	1,250	1,750
Average wind velocity in the layer, m/s	5.00	5.33	6.26	7.13	8.02	7.28	7.56	7.81	7.20
Weather category according to Pasquill	C	C	C	C	C	B	B	B	A
Share of total release activity in the layer	0.01	0.01	0.03	0.15	0.38	0.20	0.10	0.07	0.01
Rate of dry deposition of radionuclides, m/s	0.75	0.60	0.50	0.40	0.35	0.25	0.15	0.07	0.008
Release dispersion angle (0 degrees - direction to North), degrees	5	5	10	15	25	35	45	55	65



Assessment of fallout density (by Sr-90) in 100-km zone, using the modified "TRACE" package.

Level 0	-	<1	Ci/km^2
Level 1	-	>1	Ci/km^2
Level 2	-	>2	Ci/km^2
Level 3	-	>4	Ci/km^2
Level 4	-	>10	Ci/km^2
Level 5	-	>100	Ci/km^2
Level 6	-	>1000	Ci/km^2

Figure 4: Immediate Effects Due to Americium Bomb in New York City



Inner Ring:	All people must receive medical supervision
Middle Ring:	Maximum annual dose for radiation workers exceeded
Outer Ring:	Area should be evacuated before radiation cloud passes

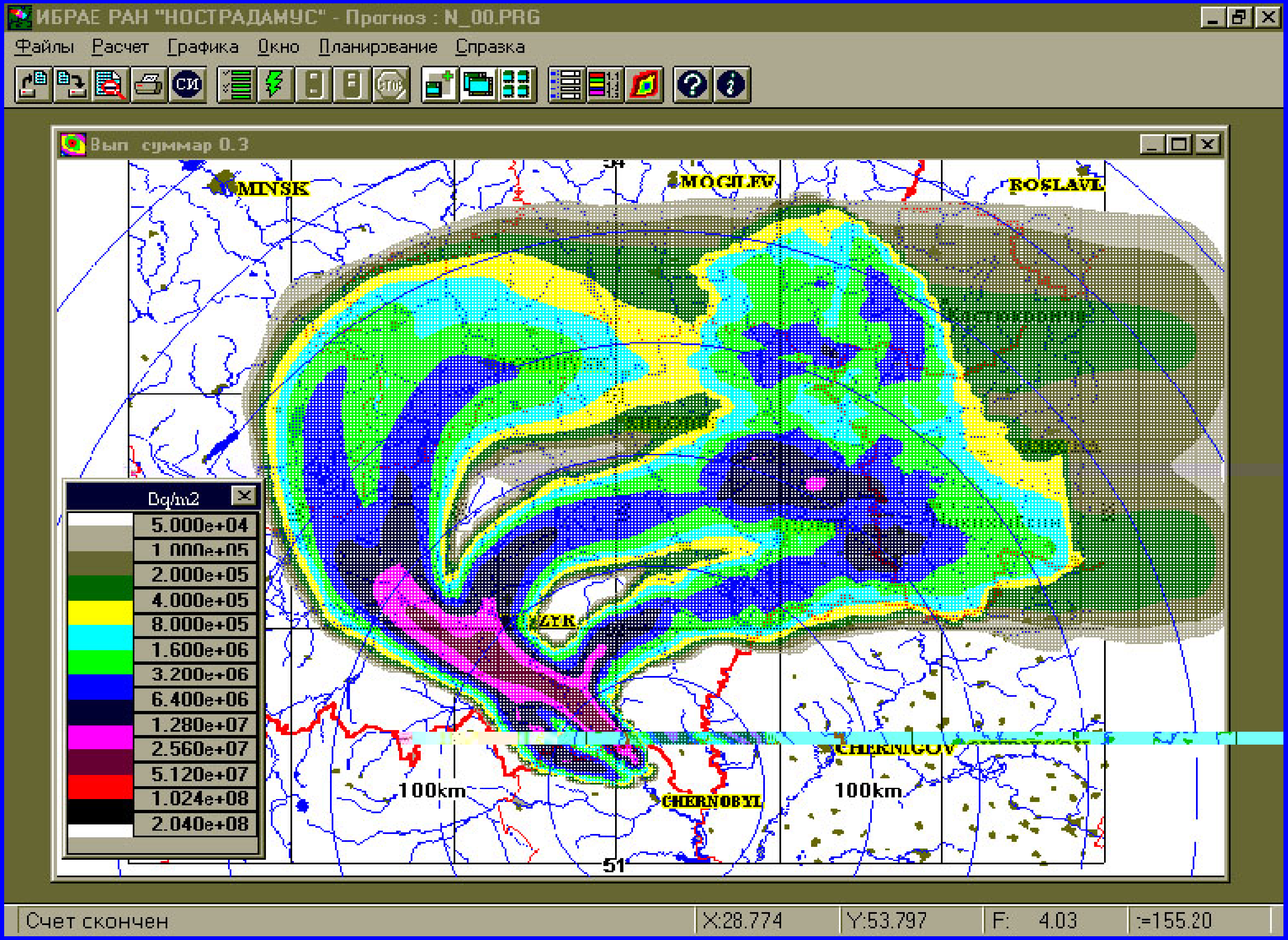
Testimony of Dr. Henry Kelly, President Federation of American Scientists

before the

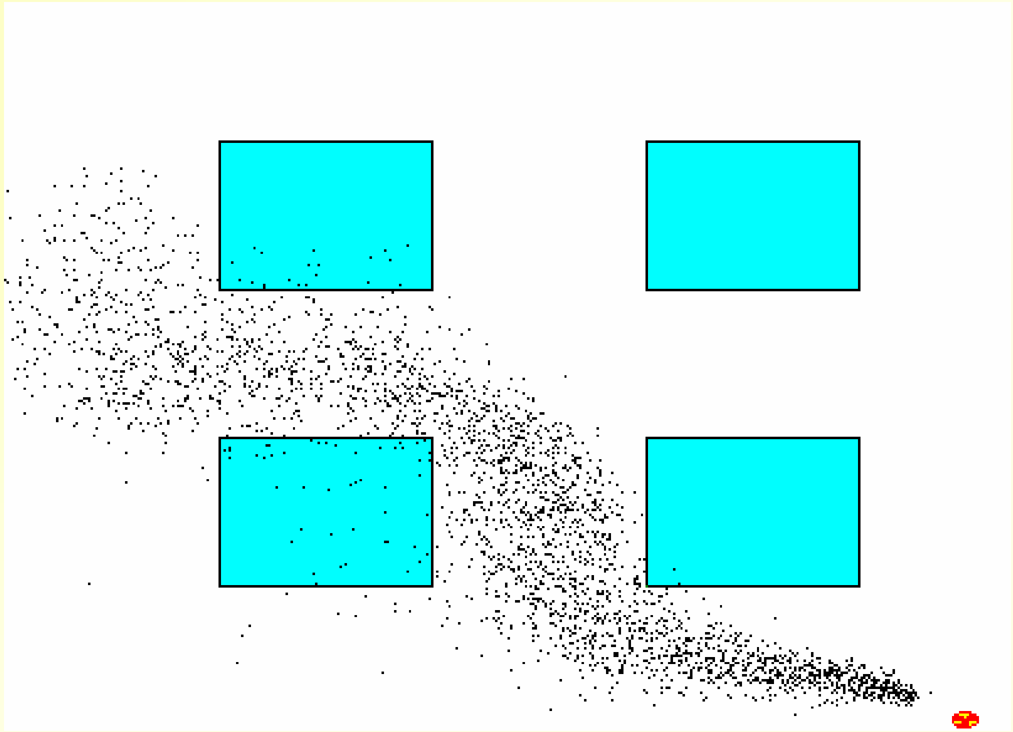
Senate Committee on Foreign Relations (March 6, 2002)

«Dirty» material - Am-241, from a typical americium source used in oil well surveying. Power of the explosive device - 1 pound of TNT.

^{131}I contamination density as of April 30 1986 as a result of releases of 6:00 a.m. - 3:00 p.m. April 27,1986 (NOSTRADAMUS Code)



Example of using the “Nostradamus” computer code for assessing the radiological consequences of a radionuclide accident under urban conditions



TECHNOLOGY PARTNERSHIPS FOR EMERGENCY MANAGEMENT

Argonne National Laboratory, July 20-23, 1998

L. Bolshov - Director of IBRAE RAS (Russia)

How to set priorities in nuclear terrorism:

- *weapons materials*
- *radioisotope sources*

Nuclear Safety Institute,
Russian Academy of Sciences

RADIOLOGICAL TERRORISM

Bolshov L., Arutyunyan R., Pavlovsky O.

Russian-American seminar

«Terrorism in High-Technology Society: Modern Methods of Prevention and Fighting Against Its Manifestations»

4-6 June 2001

One of the possible means of assessing the admixture spreading in urban conditions is numerical modeling using the distributed model based on Navier-Stocks equations with natural variables in the approximation of low compressibility together with temperature equation.

Over 10 years, in the Nuclear Safety Institute of Russian Academy of Sciences (IBRAE RAN) have been developing the 3D-model and computer code for modeling heat and mass transfer of incompressible and low compressible liquid dynamics for complex geometry and a wide range of boundary conditions.

The model is based on the solution of Navier-Stocks equations and the energy equation in natural variables and allows simulation of contamination spreading in the wide range of Reynolds and Relay numbers for both laminar and turbulent flows, and for complex geometry.

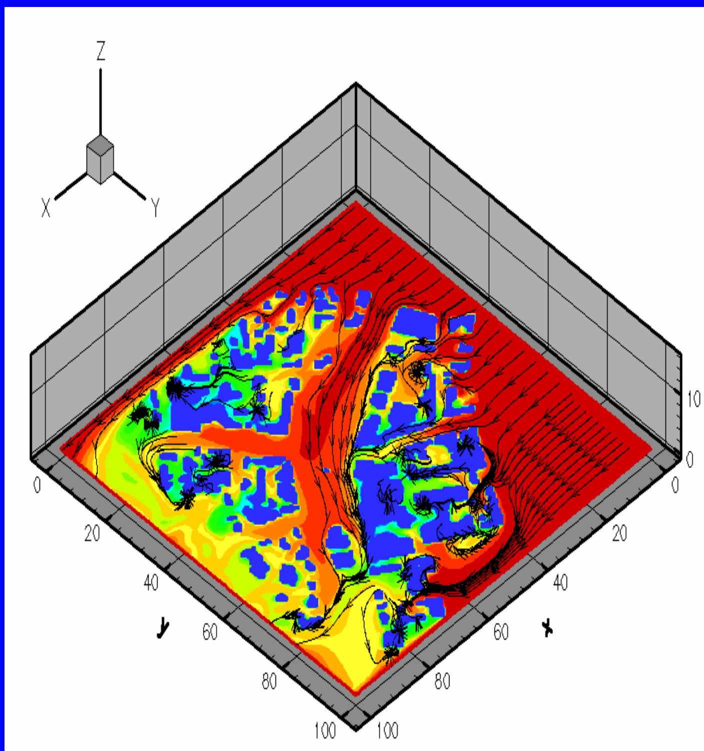
The main features of the calculation algorithm

- Discrete approximations are built using the finite-volumetric methods and spased grids of MAC-type. Also, aligned and non-aligned grids are used in calculations;
- Duglas-Rackford operator splitting scheme (similar to SIMPLEC method) is used for implicit scheme of non-stationary hydrodynamics equations construction;
- Operators in motion equation are split in two parts. The first part is connected with the velocity convection/diffusion transfer, and the second part is connected with pressure gradient.
- Method of fictitious region is used for working with irregular complex calculation regions;

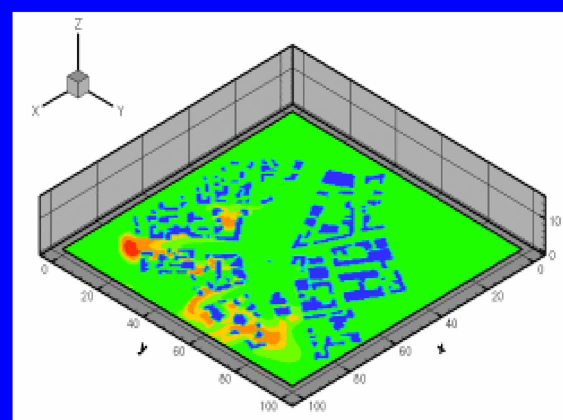
The main features of the calculation algorithm

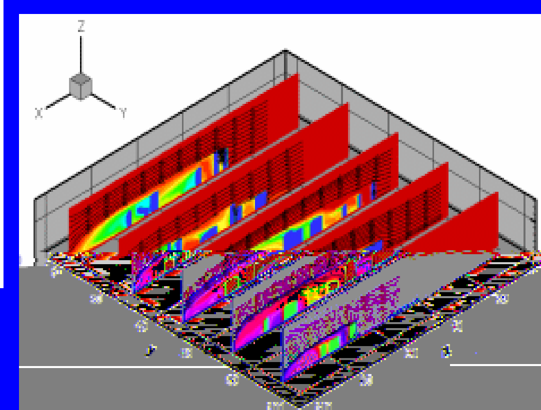
- We use the version with extension on lower derivatives, which can be physically interpreted as introducing of a porous medium model in motion equation. Different formulae can be used for flow resistance in the upper mentioned equations (for example, step function for a sharp switching of the process, linear Darsi, etc.);
- Fully implicit scheme (inverted differences) is used for non-stationary heat conductivity equation;
- For solving the convection problem, regularized non-linear monotonous operator scheme of splitting is developed in the motion equation.

3D Distributed Transport Model of Pollution in Urban Conditions



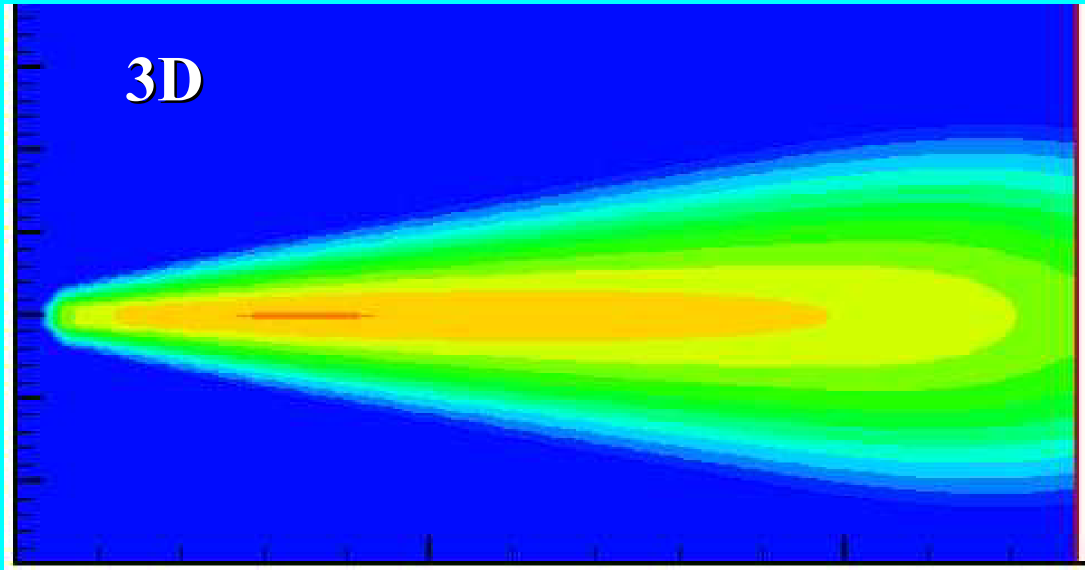
From the end of 2001 in IBRAE the activities on preparation the new 3D Distributed Transport Model of Pollution in Urban Conditions was started.

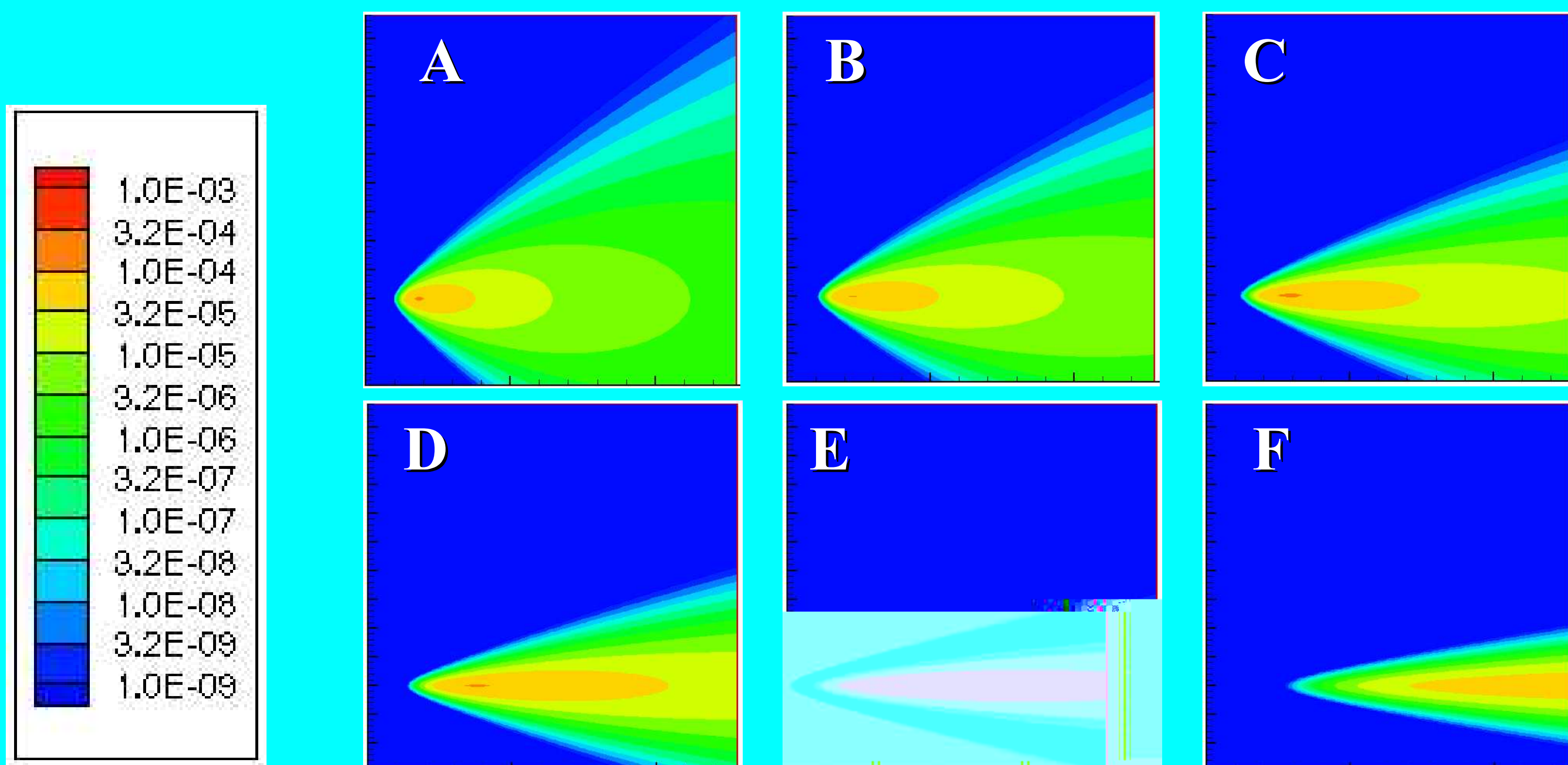




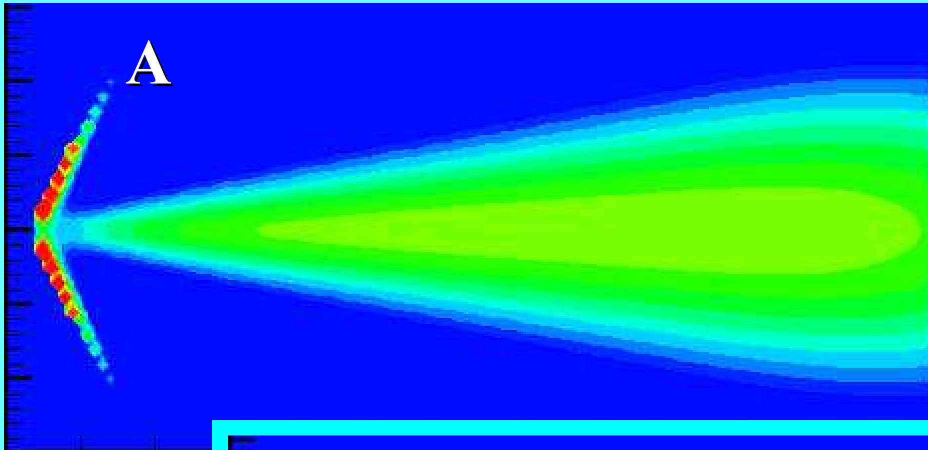
At the first stage of the calculations, an attempt of comparing the results of calculations of admixture meteorological dilution factor (in case of fairly smooth landscape), obtained by dynamic 3D and standard Gaussian dispersion models, has been made.

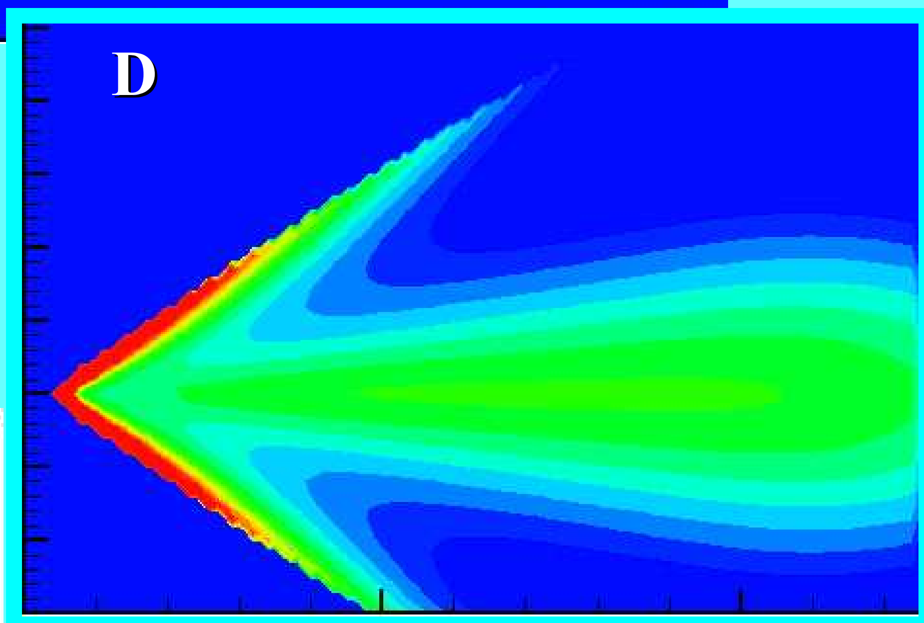
Meteorological dilution factor (H=1-2 m) calculated with using 3D and Gaussian models,sec/m^3

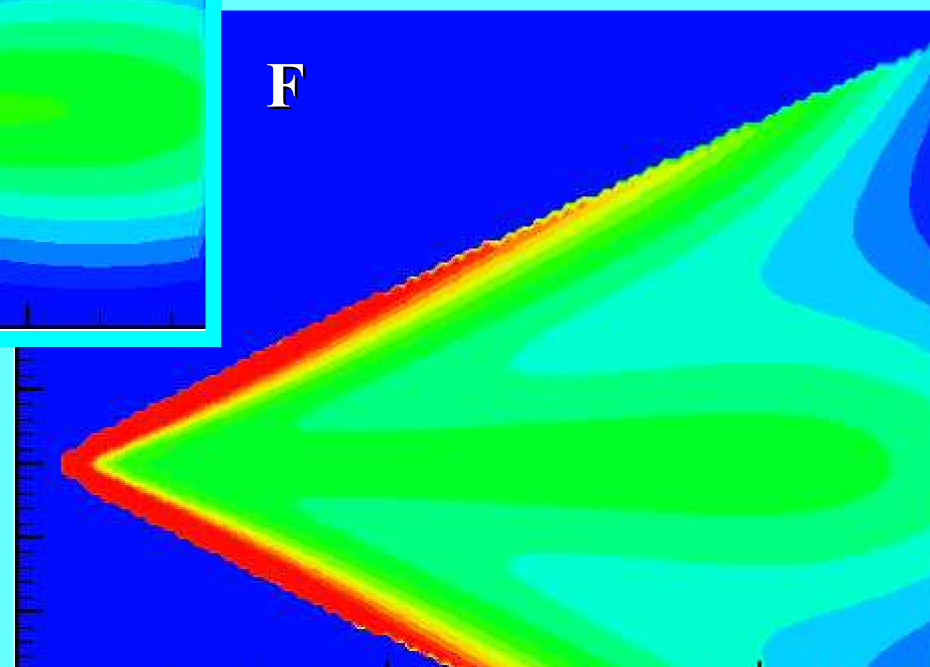


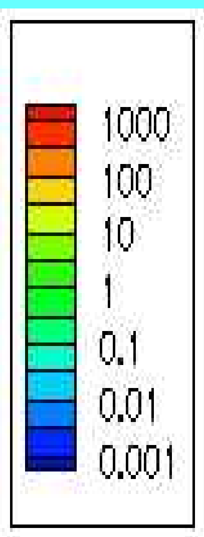


The ratios of meteorological dilution factor (MDF) calculated with using 3D and Gaussian models (H = 1-2 m)

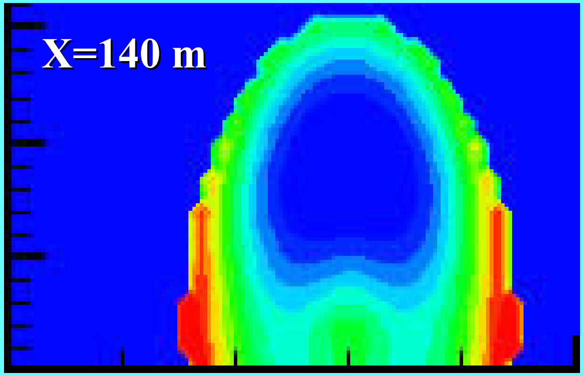


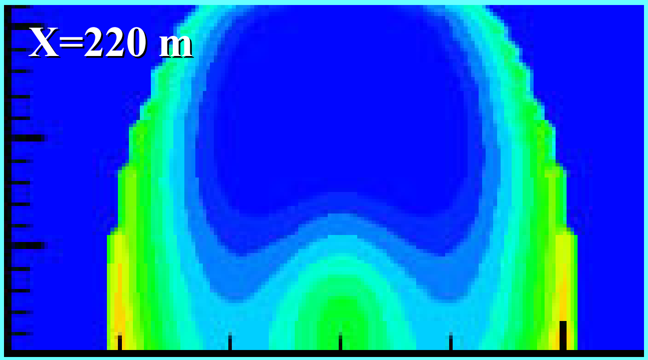


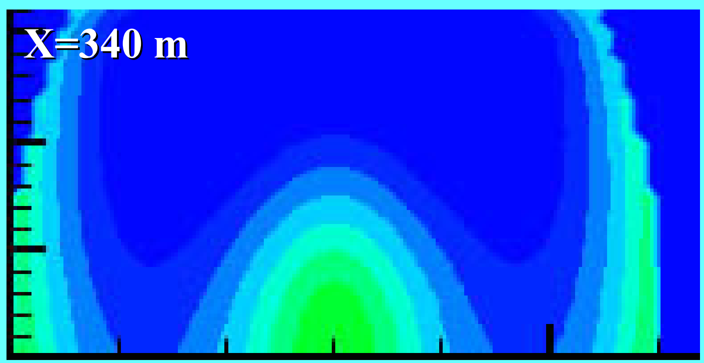


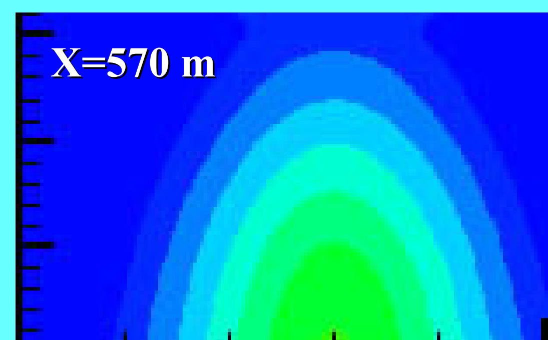


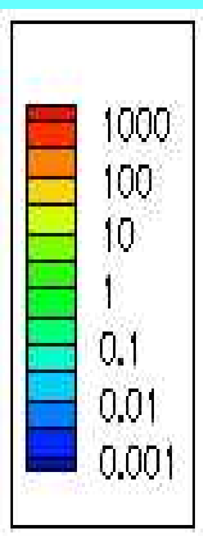
Profile across the radioactive cloud of MDF ratios calculated with using 3D and Gaussian models (Weather conditions - D)



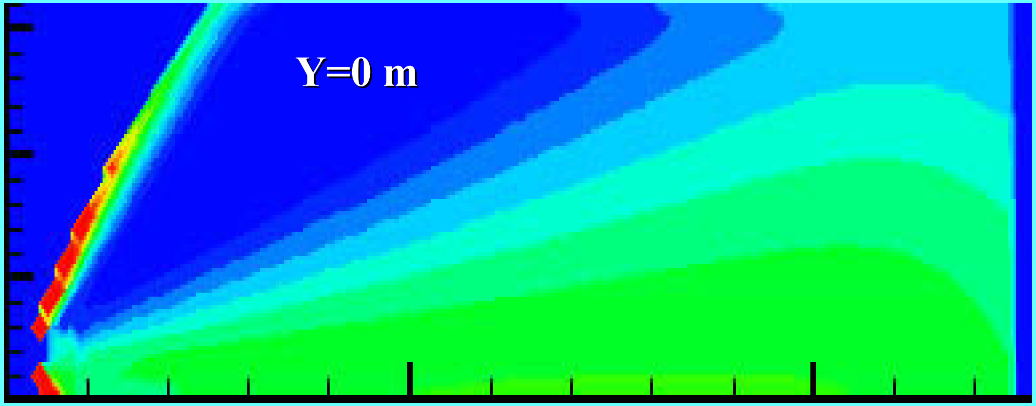


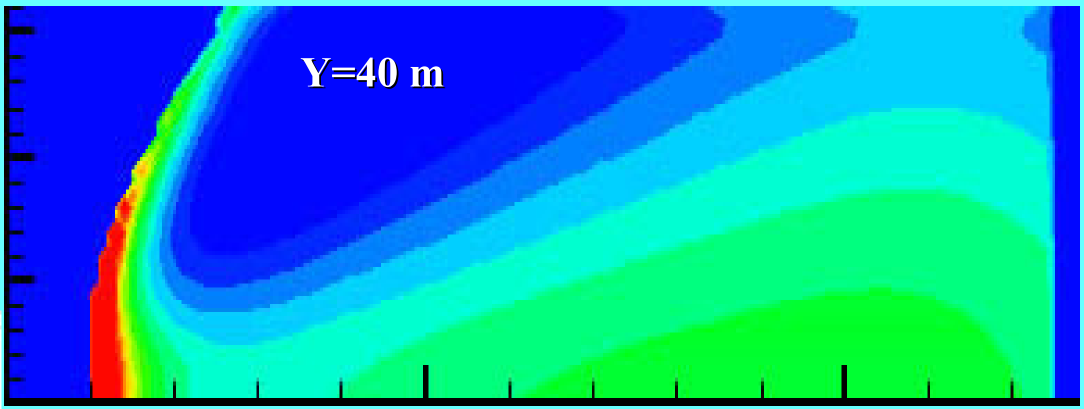


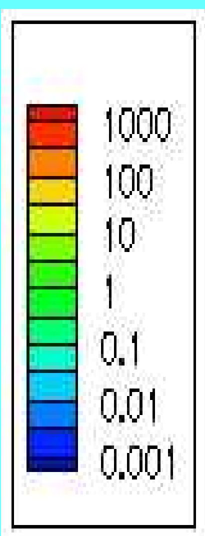


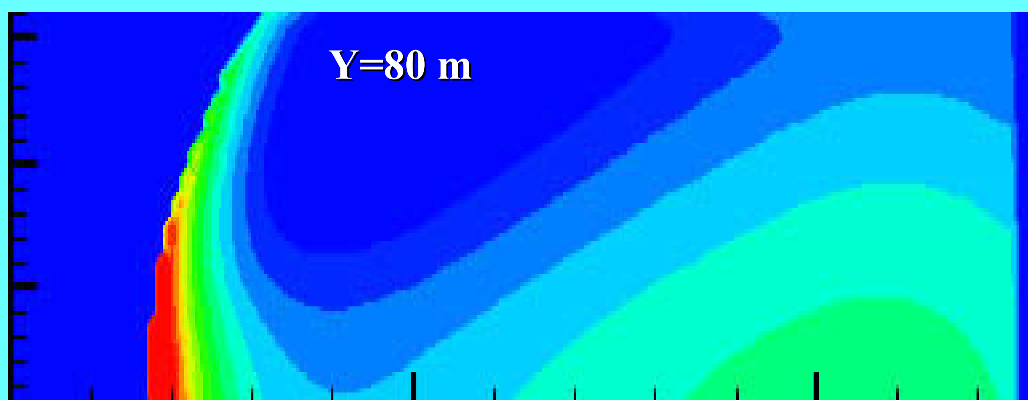


Profile along the radioactive cloud of MDF ratios calculated with using 3D and Gaussian models (Weather conditions - D)





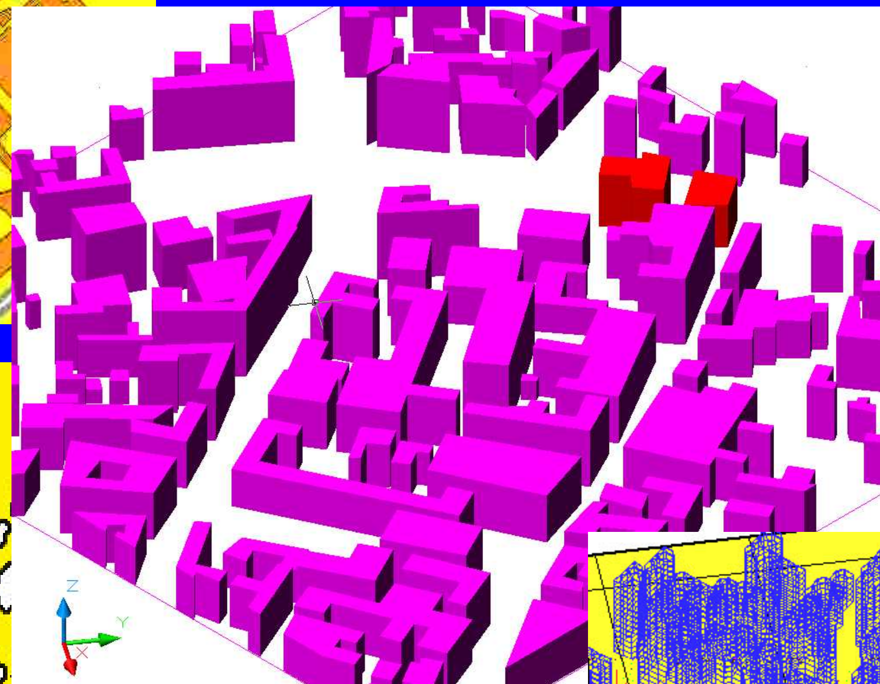


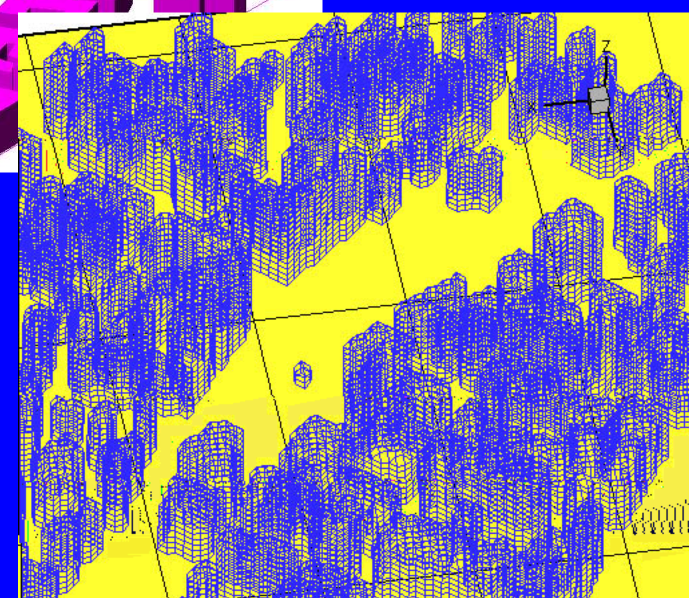


The developed distributed dynamic 3D model of admixture transfer in urban conditions on the basis of incompressible and low compressible flows is used for calculation of model task of atmospheric dispersion in complex urban conditions.

Real area of one of Russian cities was taken as an example.

Conversion 2D map to 3D digital model of the urban area





The basis data for testing calculations:

Radioactive filling of the “dirty bomb” - the Am-241 source used in oil well surveying;

Activity of source - *** GBq;

Power of blasting - ** kg TNT;

Initial height of the radioactive cloud - 20 m;

Weather conditions - neutral atmospheric stability,

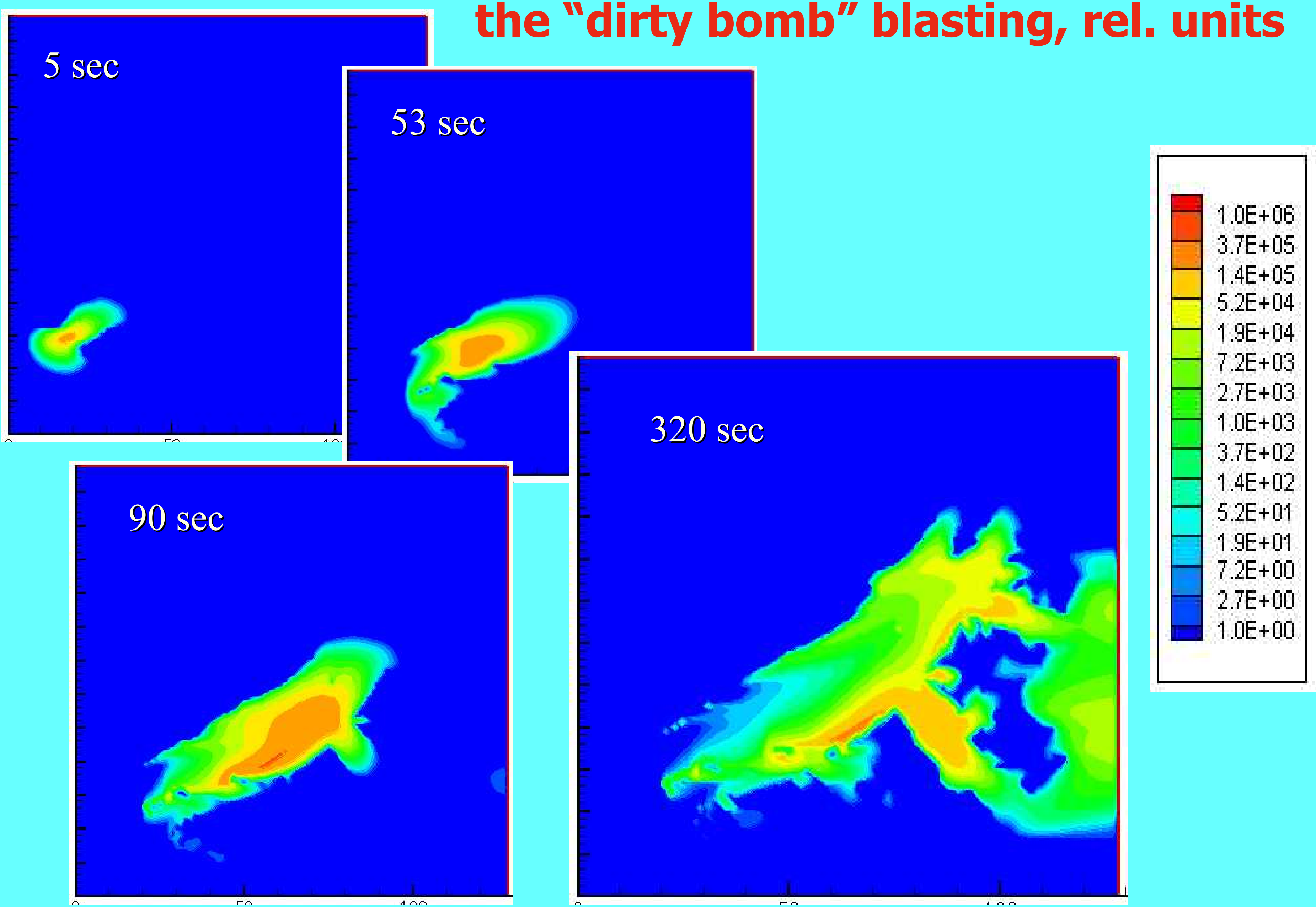
wind speed (10 m) - 5 m/s;

Calculation zone - 1 sq.km;

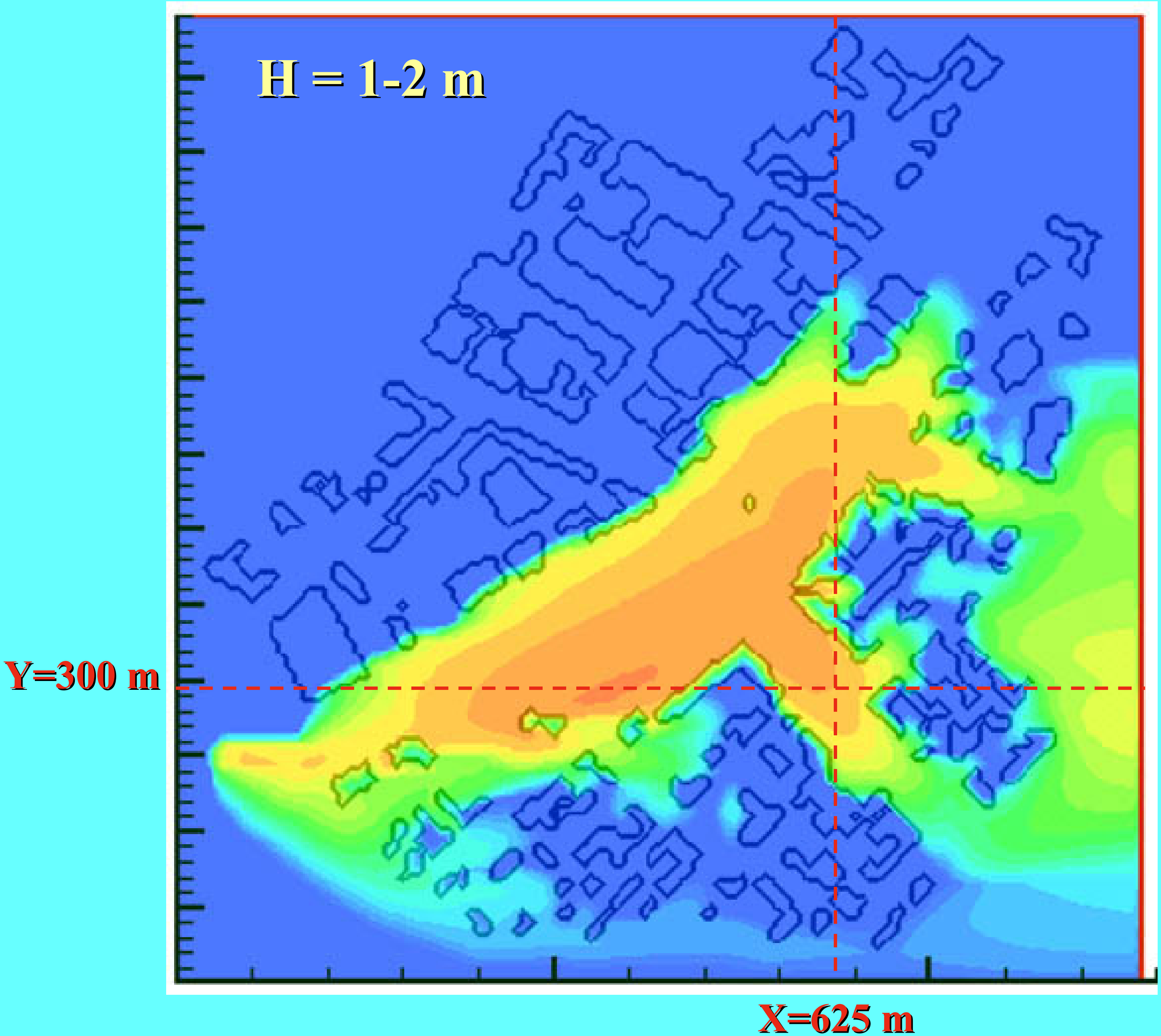
Population density - 10000 person for 1 sq.km;

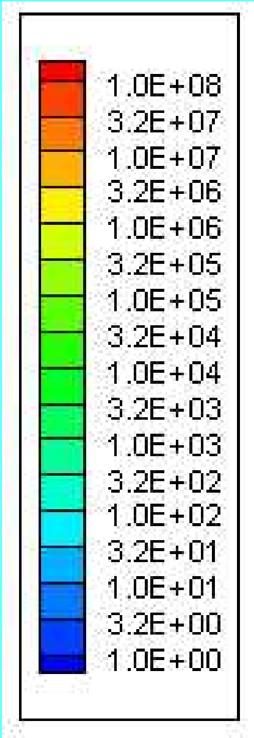
In the blasting time - 50% of people are inside and 50% are outside the buildings.

Dynamic of Am-241 air concentration after the "dirty bomb" blasting, rel. units

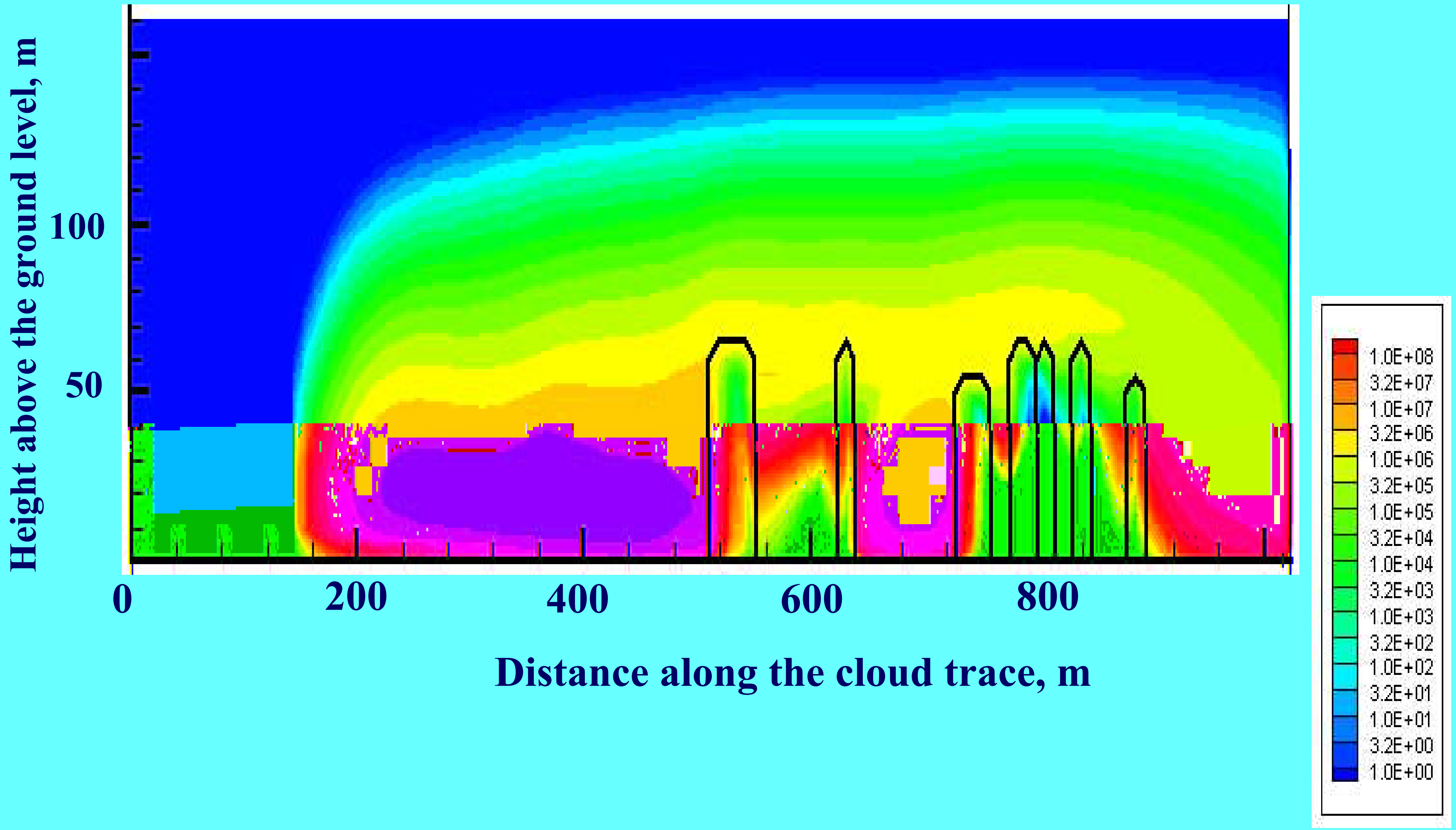


Time-Integrated Air Concentration (TIAC) of ^{241}Am after the "dirty bomb" blasting, rel. units

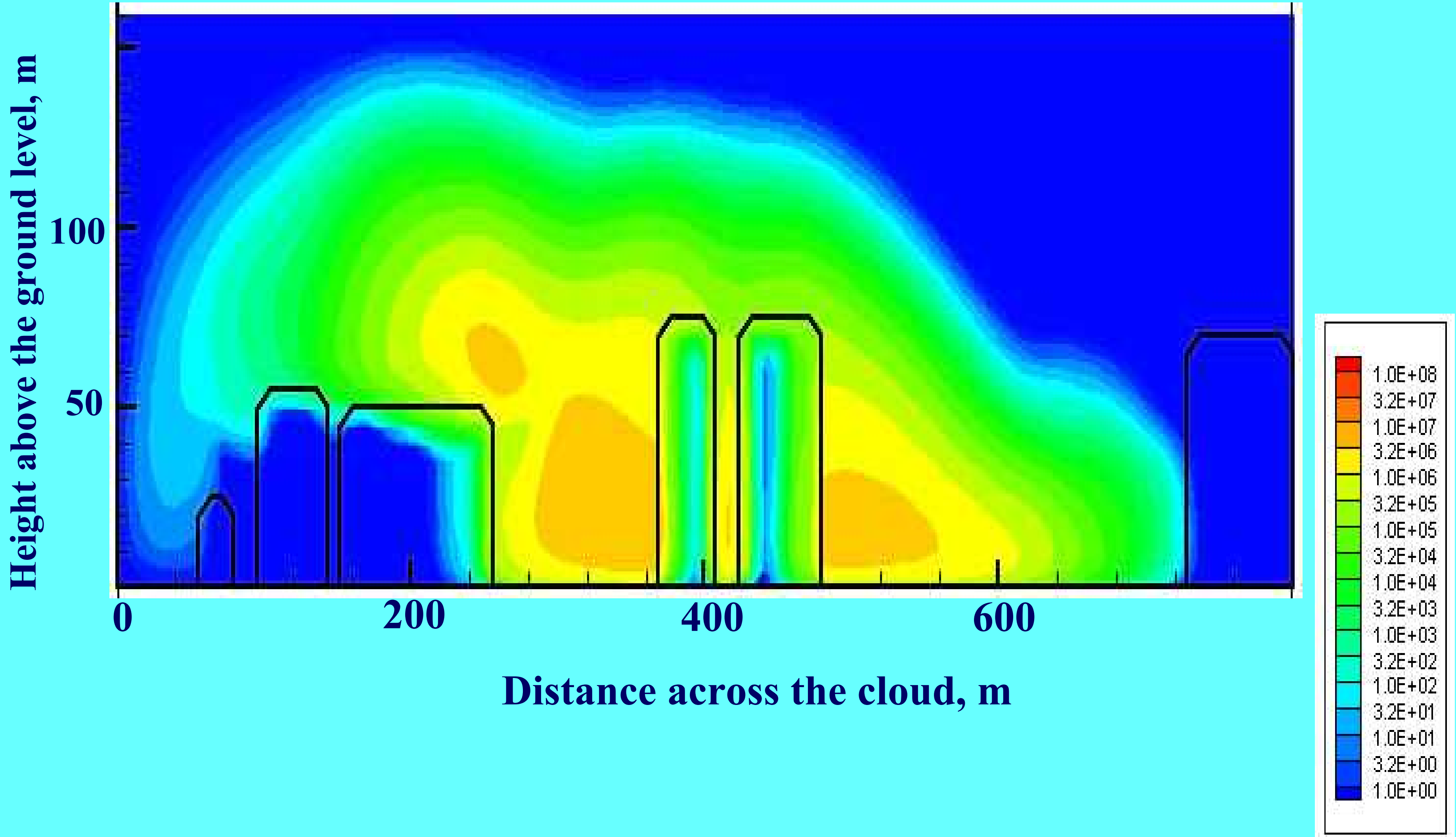




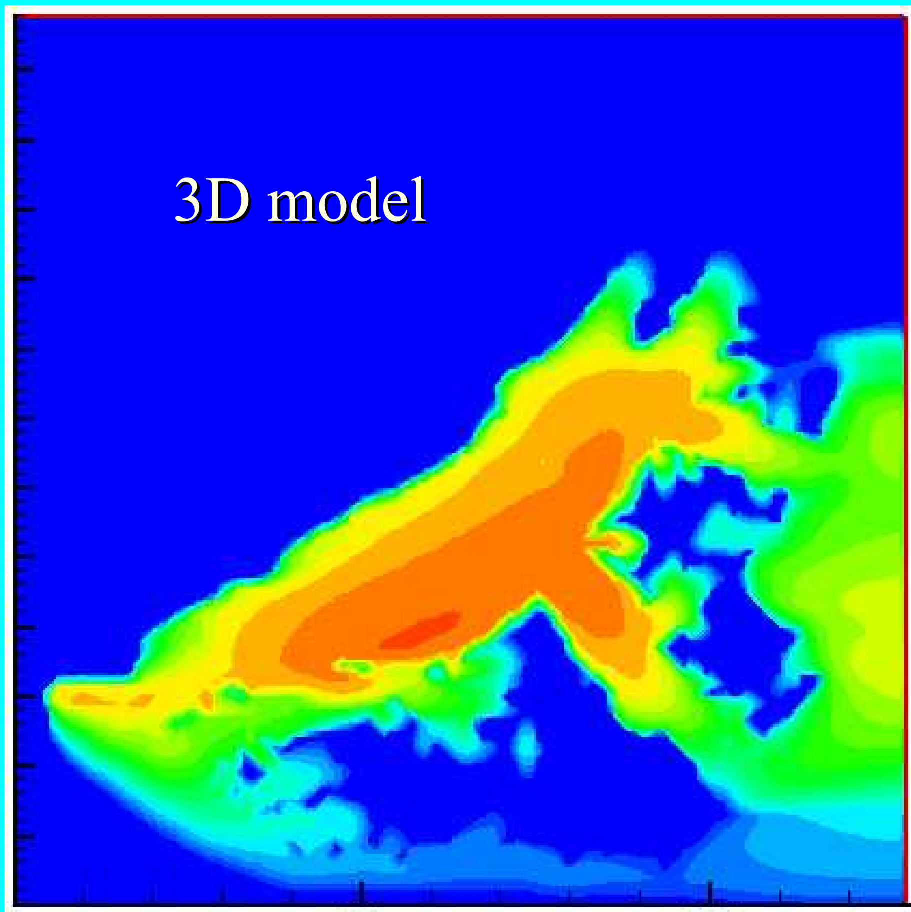
^{241}Am TIAC profile along the radioactive cloud trace (y=300 m) after the "dirty bomb" blasting, relative units

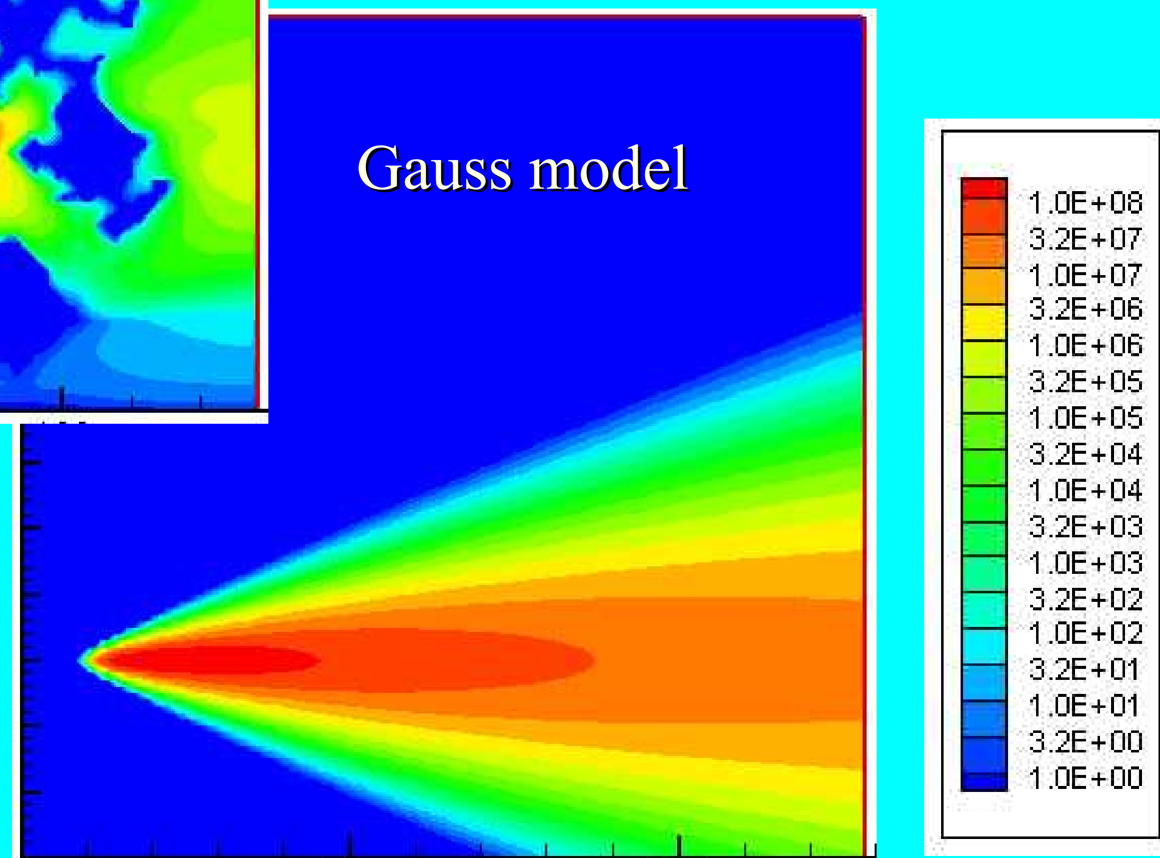


^{241}Am TIAC profile across the radioactive cloud (x=625 m) after the "dirty bomb" blasting, relative units

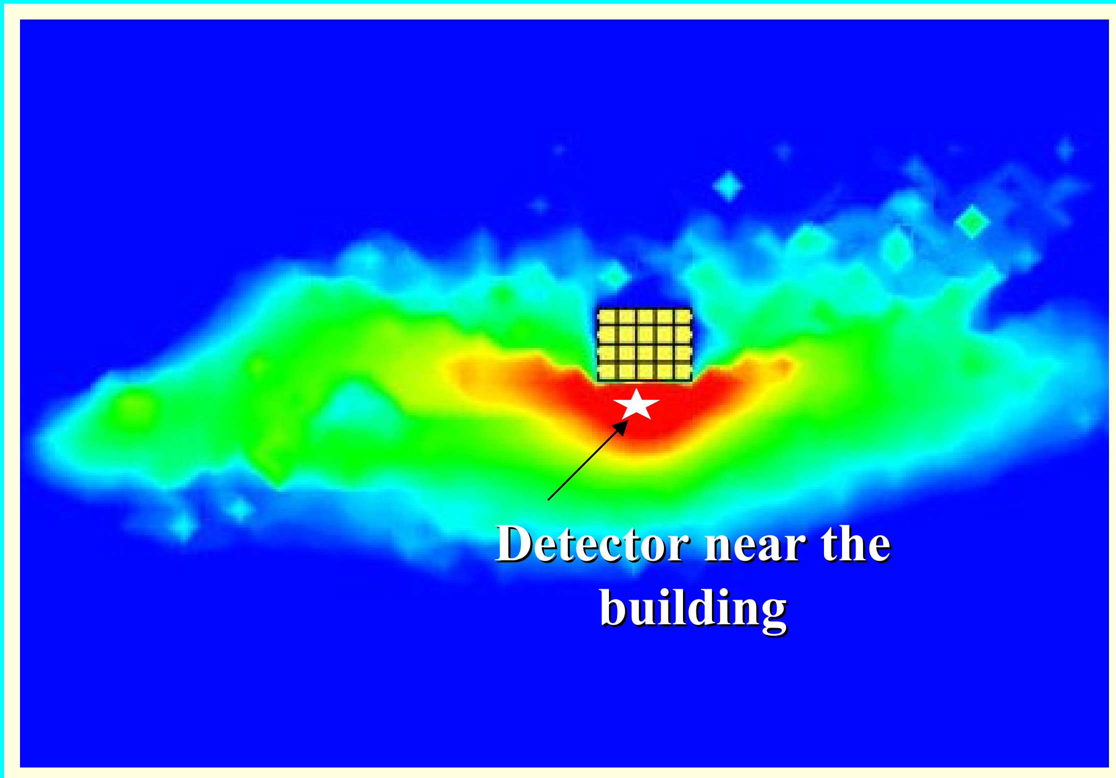


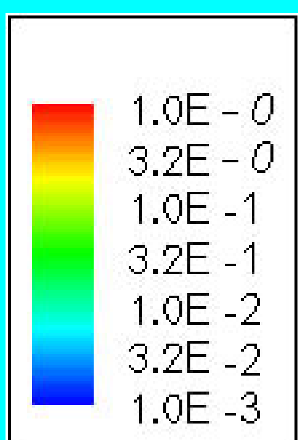
^{241}Am TIAC at H=1-2 m after the “dirty bomb” blasting, relative units

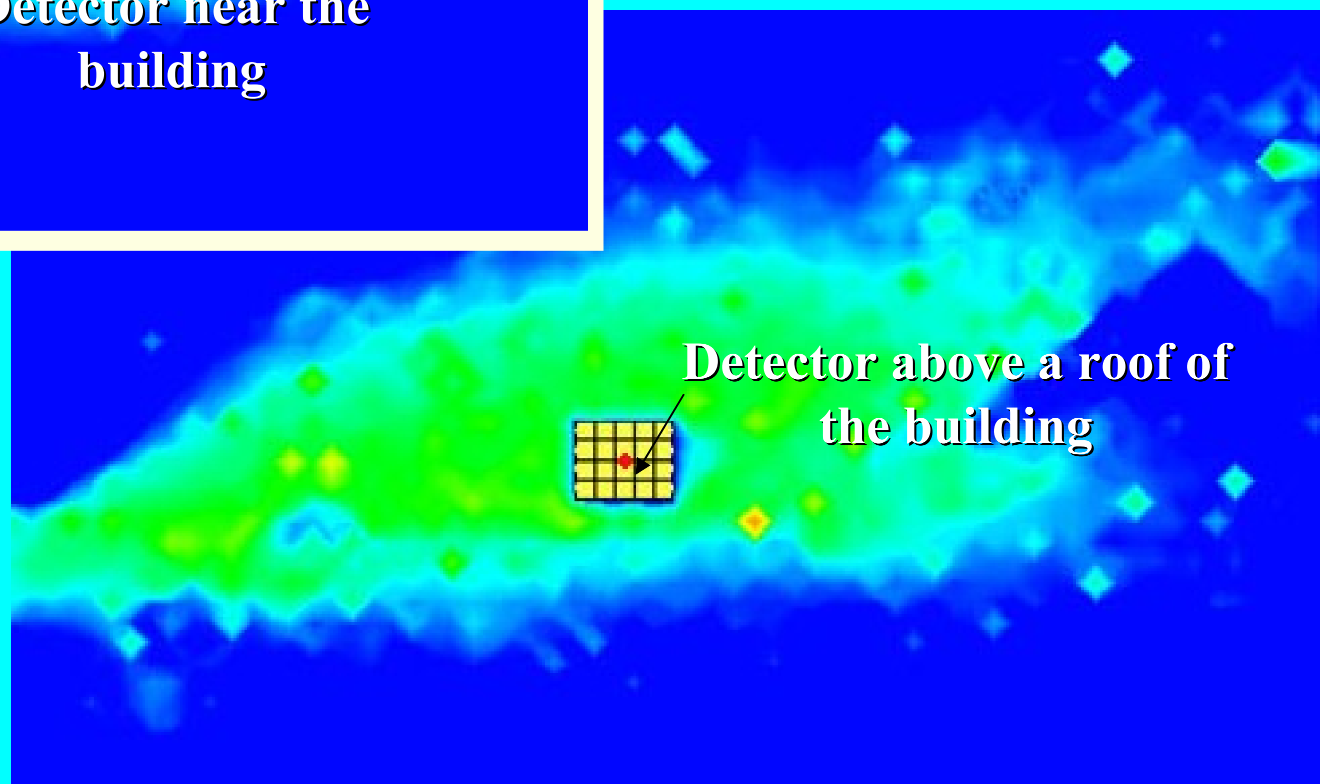




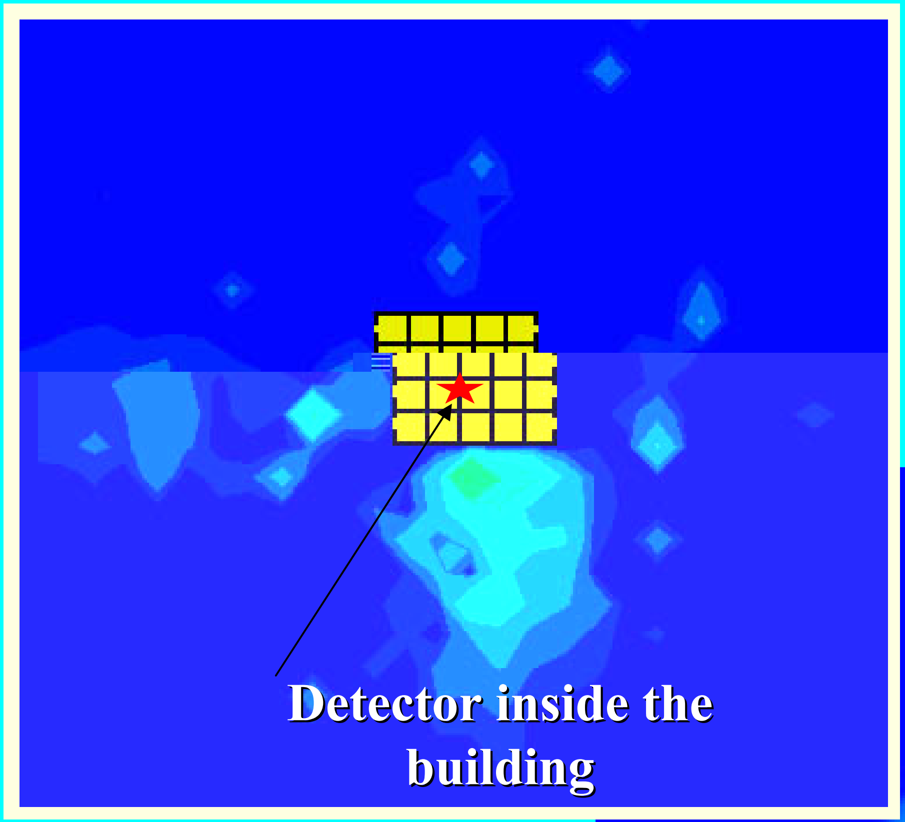
External Gamma Dose Rate from the contaminated ground after the “^{137}Cs dirty bomb” blasting, relative units

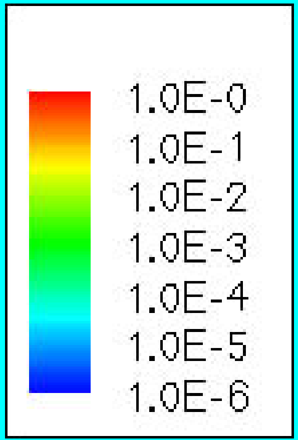


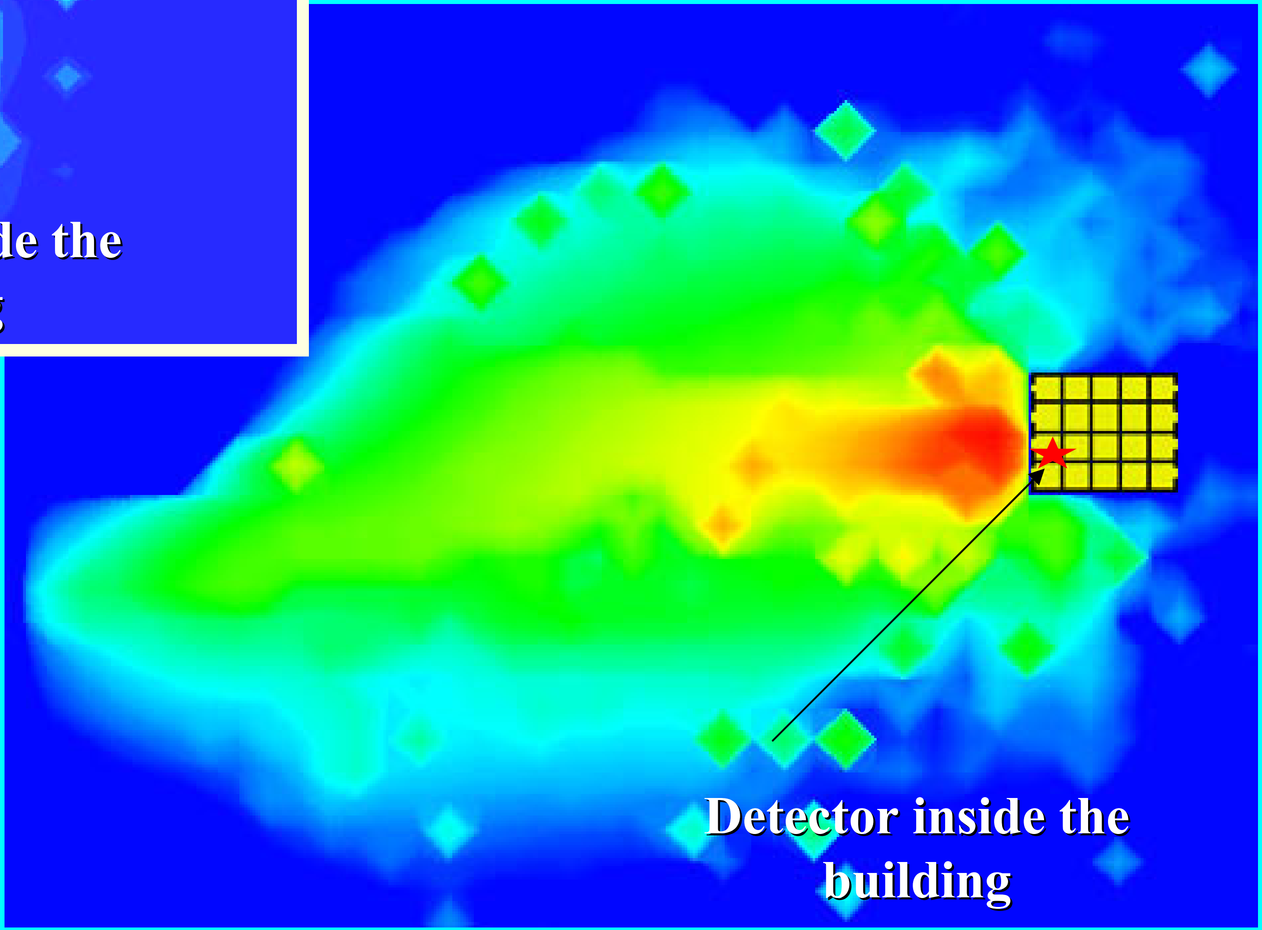




External Gamma Dose Rate from the contaminated ground after the "^{137}Cs dirty bomb" blasting, relative units







On the basis of these calculations, values of possible effects of such radiological terrorism act were estimated. The consequences turned out to be serious and spread up to considerable distance from the blasting.

Work in this direction will continue both from the point of view of improvement of the calculation model and from the point of view of counteracting the radiological terrorism and elaboration of practical advice on minimization of possible population losses.

Presented results demonstrate the possibility of using of the offered distributed 3D model for assessment of consequences of radiological terrorism acts in urban conditions.

It can be stated that addition of this 3D model of admixture transfer in urban conditions to contemporary geographic information technologies will allow automating of tasks on spreading of radioactive substances and other pollutants in urban conditions.

Given acute urgency of the problem an international research is needed to work out recommendations to minimize the very possibility of terrorist acts using RDD or “dirty bombs”.

Should such terrorist acts happen the efforts should be aimed at lessening the damage incurred due to direct radiation effects and in-direct effects on a society and economy.